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The Role of Advanced Science in Mitigating the Biological Weapons, Public Health and Environmental Threats in Central Asia

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Introduction

Daunting environmental, public health, and proliferation problems exist in the Aral Sea region of Central Asia, which together represent significant threats to both regional stability and international security. These problems extend across the political boundaries of Kazakhstan and Uzbekistan, two countries that lack adequate resources to address and mitigate these threats. A series of integrated, international and cooperative scientific projects could substantially reduce the threat to regional stability and international security posed by these problems.

The Threats

The biological weapons legacy of Vozrozhdeniye Island, which is divided between the republics of Kazakhstan and Uzbekistan, represents a proliferation and public health threat to the region and the international community. The possibility exists that virulent and viable pathogenic material could be intentionally acquired from the island. In addition, the possibility exists that the biological-weapons agents buried on Vozrozhdeniye Island could have spread naturally to the mainland through rodent, bird or other wildlife vectors. Because many of these pathogens could cause zoonotic diseases – which can be spread from animals to humans – infected animals could place humans on the mainland or in the wider region at risk of contracting dangerous diseases.[2]

The changing ecology of the Aral Sea region has exacerbated this threat of biological-weapons proliferation. The size of Vozrozhdeniye Island has expanded considerably in 40 years, growing from 200km^2 in 1960 to 2000km^2 today. There is now a small land bridge from the mainland to the island on the Uzbekistan side, and individuals regularly venture onto the island searching for scrap metal.[3]

In the early 1960s, Soviet planners diverted the Syr Dar'ya and Amu Dar'ya rivers into irrigation canals to support cotton farming in Central Asia. As a result, the sea has receded 70 miles, its surface area has decreased by 40 percent, and its volume has decreased by 60 percent. Inflows from the Amu Dar'ya and Syr Dar'ya into the Aral Sea are today 10 percent of what they were in 1960. Groundwater tables in the region have dropped from three to eight meters below the surface, and 85 percent of the region's wetlands have disappeared. Consequently, the region has experienced catastrophic losses in biodiversity.[4]

The water that has flowed into the Aral Sea has had extremely high levels of salts and dangerous contaminants. The salinity of the Aral Sea has more than quadrupled in 40 years, increasing from 10 grams per liter in 1960 to approximately 45 grams per liter in 2000. As the Aral Sea has dried up, these salts, herbicides, pesticides and other fertilizers have remained on the surface of the exposed seabed. The region's strong winds generate clouds of these toxic substances that rage across the region at least 60 days a year.[5]

In addition to the toxic dust storms, the region's rivers are silted over and the region's drinking water is contaminated with high concentrations of salts, agricultural chemicals and biological contaminants. The region's drinking water contains close to six grams of salt per liter, a level four times higher than the World Health Organization standard. Poor air and water quality have directly contributed to a horrendous state of public health. Esophageal cancers are 15 times more prevalent in this region than the average across the former Soviet Union. Typhoid, paratyphoid, viral hepatitis, dysentery, and kidney, liver and immunological diseases are unusually common. This region has the highest rate of tuberculosis in all of Europe – as high as 400 cases per 100,000 people. Infant mortality in the Aral Sea is four times higher than the average across the former Soviet Union. Geography scholar Arun Elhance has described the state of public health in this region as "the worst of all developing countries."[6]

For those people in the region who have retained their health, there are few if any economic opportunities. The toxic dust clouds in the Aral Sea region have poisoned farmlands over hundreds of thousands of square kilometers. The once thriving fishing industry, which generated 48,000 tons of fish per year and employed 60,000 people, has virtually disappeared. The annual economic damage to the region is estimated at $500-600 million for agriculture and $60-90 million for fisheries. In the first half of the 1990s, Central Asia became home to over 270,000 refugees from the Aral Sea region – over five percent of the population in a region of only five million people.[7]

Decontamination

The widely known biological weapons legacy of Vozrozhdeniye – particularly the existence of a burial ground for large amounts of anthrax bacteria, a hearty microbe that can remain virulent and viable over long periods of time – may require international cooperation and assistance to decontaminate the island. There are various possible *in situ* and soil displacement decontamination methods, though there is little historical precedent for such operations.

In the mid-1980s, the British decontaminated their former testing site on Gruinard Island off the Scottish coast. The British had used Gruinard as an open-air test site for weaponized anthrax during the Second World War. Soil sampling and analysis had been conducted annually following the war, suggesting that sporadic anthrax outbreaks in animals on the mainland were linked to Gruinard. This spread of anthrax likely originated from dead sheep carcasses, which had been discarded among the rocks on the shore of the island in 1942-3. In 1978, monitoring revealed that a three-acre area of the 550-acre island remained contaminated with anthrax spores within the top few centimeters of the surface soil. By 1985, the British determined that a five percent solution of formaldehyde in seawater, applied at a rate of 50 liters per square meter, was effective in killing the anthrax spores and did not cause the soil to become infertile. During the summer of 1986, British technicians treated approximately ten acres of the island. Extensive post-decontamination monitoring revealed positive anthrax contamination in nine out of 284 samples. Those specific areas were retreated in 1987, and subsequent sampling found no trace of anthrax. After careful epidemiological monitoring of a flock of sheep on the island, the Ministry of Defense declared the island safe for animals and humans and, in 1990, returned it to the heirs of its original owners.[8]

Gruinard and Vozrozhdeniye islands differ considerably in size and climate. Most importantly, vast amounts of pure biological pathogens were not buried on Gruinard. The contamination on Gruinard was primarily a surface problem that did not require a deep-penetrating decontamination solution. To date, inadequate research has been conducted to test how well various decontamination liquids, such as formaldehyde, bleach, or other high-technology formulations, can percolate through soil and remain effective at destroying pathogenic material. Other *in situ* methodologies, such as a thermal approach that would use heat, pressure and steam to kill anthrax spores, may require too much power[9] and equipment for them to be economically and logistically feasible.

In light of these limitations related to the *in situ* decontamination methods, soil displacement and incineration may be the most appropriate option. However, this approach has its own risks and limitations. For instance, digging up buried pathogens could result in the aerosolization of the pathogens, posing a danger to the decontamination workers and/or the human populations down wind. Ensuring that the soil is moist would reduce the amount of dust and the likelihood of aerosolizing pathogens. Using this approach, the decontamination team could also consider using a chemical formulation, instead of seawater, as the dust suppressant. This method would almost eliminate the chance of aerosolizing virulent bacteria. However, traditional decontamination formulations, such as formaldehyde, bleach, and others based on chlorinated solvents, are highly toxic and/or highly corrosive. Those individuals concerned about further polluting the Aral Sea environment would likely oppose the use of large amounts of these materials on Vozrozhdeniye Island.

Sandia National Laboratories has recently developed a non-toxic, non-corrosive chemical/biological decontamination formulation that has been proven to achieve a seven-log kill of anthrax spores after one hour of exposure.[10] The formulation – a cocktail of ordinary substances found in common household products – neutralizes chemical and biological agents in a manner similar to how a detergent lifts away an oily spot from a stained shirt. Its surfactants (like those in hair conditioner) and mild oxidizing substances (like those in toothpaste) chemically digest the agent, seeking out the phosphate or sulfide bonds holding the molecules together and chopping the molecules into nontoxic pieces.[11]

Thus, the Sandia formulation, which can be deployed as a foam, fog or liquid spray, is environmentally friendly, presents no danger to human (or animal) health, and can destroy viable and virulent anthrax bacteria as effectively as any other decontamination solution currently available. It could be used both as a dust suppressant and an equipment decontamination technology. Additional research could determine the Sandia formulation's ability to percolate through soil to kill buried anthrax. A successful experiment, especially if it were also proved that the formulation could work as well with seawater as freshwater, would make possible an *in situ* decontamination procedure on Vozrozhdeniye Island, at least in certain locations. An *in situ* alternative, which would not require large amounts of heavy earth-moving and earth-digging equipment to be flown into and out of Vozrozhdeniye Island, would also likely be less expensive than a soil displacement and incineration option.

Environmental and Epidemiological Monitoring

Before initiating a decontamination operation, which could be a risky operation for the decontamination workers as well as the human population in the region, substantive environmental and epidemiological monitoring should be put into place and evaluated. Despite the vast amount of data on the ecological disaster of the Aral Sea, there is no scientific evidence that proves or disproves any connection between the region's widespread health problems and the biological weapons legacy of the island. Epidemiological monitoring in the Aral Sea region has not been rigorous and has been limited to studies on known endemic diseases. The epidemiological monitoring has not in any way been linked to specific soil sampling on the island. Comprehensive environmental and epidemiological monitoring, if it were designed specifically to address Vozrozhdeniye Island, could provide important reference points and markers to determine the scope of the problem and effectiveness of future decontamination efforts. Have all the areas on the island where virulent and viable pathogens exist been identified? Has the problem on the island been definitively characterized?

At this time, scientists do not know whether any non-endemic infectious material has spread beyond the island, what animals are infected and could be vectors, or what human populations are at risk. There are many rodent species in the Aral Sea region that in all likelihood live near or in the areas where the Soviets buried pathogenic material. These rodents live in vast tunnel colonies, which likely move in, through and out of the burial sites. It is estimated that over 600 tunnel colonies could exist in a one-square-mile area.[12] Specific field surveys should be conducted to assess the nature and extent of the rodent tunnels on the island and the coincidence, if any, between the tunnels and the pathogen burial sites. In addition, a comprehensive epidemiological monitoring system should aim to characterize the dynamics within each rodent species – habitat, population density, sex ratios, reproduction peaks and background presence of disease – on the island. All of this information would help establish parameters for any decontamination effort, help ensure that any decontamination operation does not inadvertently spread pathogenic material out through the rodent tunnel systems, and help define requirements for rodent and parasite control.

Specifically, both Uzbek and Kazak scientists could establish environmental and epidemiological monitoring stations on Vozrozhdeniye Island and around the Aral Sea. The meteorological stations would collect air, soil, water, rainfall, solar flux and other basic environmental data that could help determine how the local ecology influences animal health and disease spread in the region. The epidemiological stations would be open-air, semi-enclosed pens or sevietas, where rodents could be tested at regular intervals for antibodies or signs of diseases. The consistency of the monitoring methodologies and the comparability of the data from the Kazak and Uzbek monitoring stations are essential for making reliable conclusions about the nature and scope of the problem. Thus, it is recommended that all parties involved in decontaminating the island, and therefore interested in the authenticity of the data, facilitate a fully cooperative Kazak-Uzbek monitoring regime and ensure rapid and transparent sharing of data.

This environmental and epidemiological information, combined with field surveillance and soil sampling, is critical for characterizing the problem on Vozrozhdeniye Island and assessing the risk and effectiveness of various remediation strategies. In other words, comprehensive and coordinated monitoring should inform the decisions on whether and how to decontaminate the island. If specific burial sites were decontaminated without regard for the animal populations on and near the island or other areas of concentrated disease, the possibility could exist that considerable amounts of virulent and viable pathogenic material would remain after the decontamination were concluded. In addition, environmental and epidemiological monitoring specifically linked to the Vozrozhdeniye Island problem could provide a baseline assessment of the current problem, important safety information during a decontamination program, and data that could demonstrate the success of the completed decontamination.

Clinical Human Health Monitoring

Monitoring of human health, at a clinical level, could also provide information relevant to any decontamination procedure. To ensure the safety of the decontamination workers and the health of the region's human population as well as to help verify that any decontamination had not inadvertently caused an outbreak of an infectious disease, it may be necessary to implement a disease surveillance system that could provide a real-time assessment of the state of human health over a certain time and space. The surveillance would have to be implemented well before any decontamination work occurred to establish the background presence of disease. This baseline data would be required to identify whether or not a disease outbreak represented an anomaly that could be traced back to the decontamination.

Traditional disease monitoring systems, which rely on laboratory-intensive disease-diagnosis procedures, would not provide enough immediate data to affect or change the decontamination methodology. Instead, a more sensitive but less specific surveillance system, taking advantage of modern communication and data-management systems, could provide the basic clinical data in near real-time necessary to identify potential outbreaks of infectious diseases.

In collaboration with Los Alamos National Laboratory, the University of New Mexico, and the New Mexico Department of Health, Sandia National Laboratories has developed the Rapid Syndrome Validation Project (RSVP).[13] RSVP is a real-time, full-time, internet-based medical database that augments the reporting and containment of outbreaks of disease. In contrast to other sentinel networks, RSVP tracks outbreaks of *syndromes* – signs and symptoms – rather than positive diagnoses of specific *diseases*. As syndromes do not require diagnostic testing, RSVP is less specific but more sensitive than existing disease surveillance systems. RSVP helps physicians, hospitals, regional health departments and epidemiologists monitor the occurrence of illnesses that exhibit similar prodromal symptoms – symptoms that occur before the disease's full development – as most serious infectious diseases. By displaying syndromic information geographically, temporally, and immediately, RSVP allows public-health officials to distinguish between benign sicknesses and deadly diseases in a much more timely fashion than has been possible until now.

RSVP has been operational in several hospitals in New Mexico as well as the State Health Department Offices in Santa Fe since August 2000. By demonstrating that Influenza Type B was more common than Influenza Type A this past winter, RSVP motivated physicians to await clinical diagnoses before prescribing expensive drug regimens (Influenza Type B cannot be treated with medication). Additionally, RSVP has been instrumental in averting two separate outbreaks of hepatitis A after physicians were prompted by state officials to test for that disease after reviewing data collected by RSVP.[14]

The RSVP database provides immediate benefits to general practitioners and public health officials. Since serious infectious diseases often exhibit similar, fairly benign prodromal symptoms, diseases can be misdiagnosed. It is only when the disease begins to exhibit its classical or end-stage syndromal symptoms – those that occur when the disease has fully developed – that a correct diagnosis can be made. At this stage, it is often too late to help the patient and anyone that the patient may have infected. RSVP is designed to show clusters of syndromes, enabling physicians and public health officials to recognize, in a timely fashion, the possibility of a more serious illness than they had thought previously. These officials can then begin testing and, if necessary, order special treatment. RSVP accelerates the response to an infectious disease outbreak and thus improves the likelihood that it can be rapidly contained.

A syndromic surveillance system, operational in Kazak and Uzbek hospitals and public-health centers and clinics near the Aral Sea, could help determine the linkages, if any, between the island and regional public health. Moreover, syndromic surveillance could track regional public health during and after any decontamination procedure to provide confidence that the decontamination effort had not caused an outbreak of human disease. Such a syndromic surveillance system could also directly connect the regional public-health centers with the anti-plague institutes and epidemiological expertise in the region.

Consequently, syndromic monitoring could improve the safety of the decontamination operation as well as strengthen public health in the region.

Summary

The environmental and public health threats in the Aral Sea region of Central Asia are daunting but not insurmountable. However, mitigating these threats will require a multinational, multidisciplinary and scientifically sound set of technical and political solutions. Specifically, solving the problem related to the biological weapons legacy on Vozrozhdeniye Island will likely require a decontamination methodology that places a high priority on not exacerbating the already poor environmental and public-health conditions in the region. Cooperative environmental and animal epidemiological monitoring, combined and linked with cooperative syndromic human-health monitoring, would define the scope of the problem and provide confidence in the success and safety of the decontamination of Vozrozhdeniye Island. A series of international and integrated, advanced science activities could reduce the threat of biological weapons proliferation from Vozrozhdeniye Island as well as augment the technical understanding of the region's environmental and public-health difficulties.

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[9] There is no electricity source on the island. All power sources (electrical generators) would have to be flown in and out.

[10] After one hour of exposure, one anthrax spore out of 10 million remained alive. For independent testing results, see http://www.deconsolutions.com/dugway.htm.

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[12] Information received from Dr. Bakhyt Atshabar, Director of the Kazakh Institute for Research on Plague Control in Almaty, Kazakhstan (discussions in April 2001) and corroborated by Dr. Richard Poché, President of Genesis Laboratories in Wellington, Colorado (discussions in July 2001).

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